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# Energy Efficiency of the Russian Regional Economy (a case study of the Sverdlovsk Region)

**L Teslyuk, A Boyarinov and N Dukmasova**

Department of Environmental Economics, Ural Federal University named after the first President of Russia B.N. Yeltsin, 19 Mira street, Ekaterinburg, Russia

E-mail: au.boyarinov@net-ustu.ru

**Abstract.** Today, Russia has the second highest value of GDP energy intensity in the world. Among many factors that determine this indicator, special mention can be made of low use efficiency of the fuel and energy resources. This leads to a decreased competitiveness of the national economy. The aim of this paper is to identify practical challenges that serve as a barrier to the reduction of specific energy consumption and to respond with optimal solutions at the level of a territorial entity of Russia (the Sverdlovsk region). The analysis of the fuel and energy balances and the gross regional product between 2015 and 2018 enabled us to identify the changes in the pattern of fuel and energy resources consumption in individual sectors of economy, as well as influencing factors. Special attention is given to the dynamics of average specific energy consumption indicators and to the status of communal infrastructure in the housing and community amenities sector. The study revealed that reduction of technical and commercial losses due to modernization of communal systems and implementation of energy-saving technologies can be achieved through efficient management via further development of public private partnership.

## 1. Introduction

Available data [1] demonstrate the increase in global energy demand with every passing year. Between 2008 and 2018, it rose by 17% to reach 13,978 Million tonnes of oil equivalent (MTOE) primarily due to economic development of countries in Asia (37%), Africa (30%), and the Middle East (35%). The need for energy savings and enhancement of energy efficiency of national economy is fueled by the decrease in primary non-renewable energy resources, increase in their cost, environmental deterioration, and menace to energy security of the countries. Energy consumption efficiency and downward trends can be illustrated by changes in the values of energy intensity, which is the ratio of energy consumed to the country's GDP. Energy intensity is determined by many factors not just energy consumption efficiency. The report [2] published by the International Energy Agency (IEA) for quantifying the impact of various driving forces, outlines an example of three-factor decomposition analysis aimed at the determination of such elements as changes in the volume of activity, structure of activities, and energy efficiency. To determine the structure of a national economy, the following general sectors are identified: industry, services, transport, residential sector, etc., characterized by different levels of energy consumption [3]. The global economy has historically developed certain activities in different countries in accordance with their environment, geographical position, and economic resources. Though it would seem logical that the lowest energy intensity value must characterize the countries with a higher share of services in the structure of output, there are a



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sufficient number of countries with a higher share of services than the countries with minimum energy intensity listed in Table 1.

**Table 1.** Countries with minimum energy intensity.

Parameter	Colombia	United Kingdom	Romania	Turkey	Italy	Portugal	Spain	Germany
Energy intensity, kep/\$2015p	0.054	0.062	0.065	0.066	0.067	0.069	0.070	0.072
Services, % of GDP	57.8	70.5	57.1	54.3	66.1	65.0	66.9	61.5
Urban population (% of total population)	81	83	54	75	70	65	80	77
Electric power consumption (kWh per capita), 2014	1,312	5,130	2,584	2,847	5,002	4,663	5,356	7,035

The table has been compiled by the authors as per data [1, 4].

Energy intensity of an economy is determined not only by the GDP structure, but also by many other factors, such as climate, the size of a country, availability of energy resources, proportion of the urban population, consumer behaviour, technical energy efficiency, etc. [3].

Today, Russia has the second highest value of this indicator in the world after Ukraine. China has reduced it by 36% since 2007, when both countries demonstrated the same GDP PPP energy intensity equal to 0.205 kep/\$2015p, to 0.131 kep/\$2015p in 2018, while Russia reached 0,215 kep/\$2015p [1].

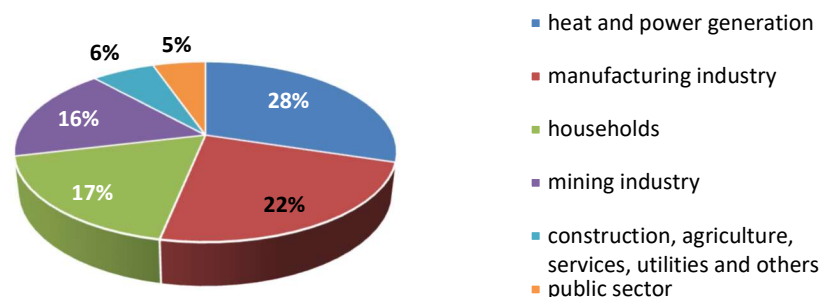
The Russian Federation consists of 85 territorial entities with different efficiency of energy resources use due to diversity of their climatic conditions and resources, as well as due to historically formed inhomogeneity of its economic area in terms of many economic and social indicators. Therefore, regional strategy towards energy savings and enhancement of energy efficiency of the economy must be formed with due regard to regional conditions, level of the development of economic relations and production, as well as social, technological, information, and financial potential.

The purpose of this article is to analyze the use of fuel and energy resources across different sectors of the Russian economy with definition of their savings through the case study of the Sverdlovsk region. The article analyzes the factors determining energy intensity of the Russian economy, outlines the problems related to the reduction of energy consumption of fuel and energy resources, and specifies the measures aimed at their solution.

This study uses the data of the Russian state and international statistics, Russian regulatory documents in energy savings and enhancement of energy efficiency of the economy, recommended practices and guidance materials, as well as works by national and foreign experts.

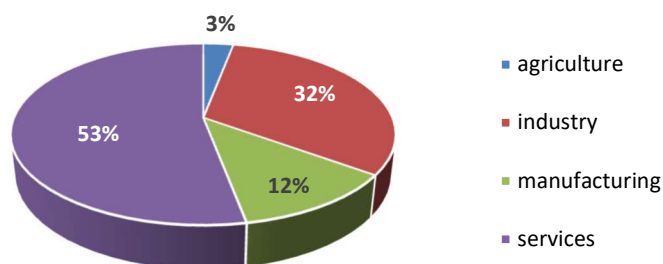
## 2. Assessment and analysis of fuel and energy resource efficiency in the Russian Federation

The Russian Federation is characterized by large fuel and energy reserves [5], such as oil (6.1% of the global total, 6th place), natural gas (19.8%, 1st place), and coal (15.2%, 2nd place). Primary energy consumption in Russia increases at an average annual rate of 1.9%. In 2018, it reached 661 MTOE [6]. The main share in the country's fuel and energy balance accrues to natural gas (60%), coal (16%), oil and oil products (13%), nuclear fuel (8%), hydropower (3%), and renewable energy resources (0.03 %). The structure of the fuel and energy consumption across sectors in the Russian Federation in 2018 is shown in Fig.1.



**Figure 1.** The structure of the fuel and energy consumption across sectors in the Russian Federation in 2018.

In terms of GDP, Russia ranks 6th after China, the USA, India, Japan, and Germany. The structure of the country's GDP across sectors of economy (Fig.2, as of 2018) between 2010 and 2018 did not undergo any significant changes [4].



**Figure 2.** The structure of the country's GDP across sectors of economy in 2018.

Thus, industrial sector in general, which accounts for 44% of GDP, consumes 66% of fuel and energy resources. Between 2010 and 2018, Russian GDP rose by 8.7%, while total energy consumption demonstrated an increase by 16.2% as per data [1]. Energy intensity of the country's GDP within the same period increased by 3.86% from 0.207 to 0.215 tep/\$2015p. If compared to China, whose main GDP share also accrues to the industrial sector and equals to 70% (2018), the following changes can be identified. Since 2010, the country's GDP has increased by 123.5% with the increase in energy consumption by 24.8%, which led to the reduction of GDP energy intensity by 30% (over the same period). The value of energy intensity is an integrated value of energy consumption and is determined by many factors that do not always depend on energy efficiency and energy savings of a national economy [7]. The state report concerning energy savings and enhancement of energy efficiency in the Russian Federation [6] shows that energy intensity of the country's GDP has not reduced over the past four years. Current state policy towards energy savings and enhancement of energy efficiency [8] is aimed at the reduction of this indicator by 40% by 2020, as compared to 2007, by means of scheduled activities specified in the Program [8] leading to energy savings by all the consumers of energy resources. Russian statistics data show that the changes in the GDP energy intensity values over the past period before 2018 differ from those given by foreign statistics [1] and is more positive, though even in this case this indicator decreases by only 9%. The assessment of the influence of individual factors on the changes in the Russian GDP energy intensity values on the basis of the approved method [9] for individual sectors of economy for the period from 2015 to 2018 through the multiplicative LMDI decomposition approach revealed the changes in energy consumption. The following factors were considered as fundamental: structural factor at the level of sectors, structural factor at the level of sub-sectors, economic activity, technological factor, climatic factor, use of production capacities, and provision of amenities (Table 2).

**Table 2.** Contribution of factors to the changes in energy consumption, mln TCE (2015-2018).

Factor	2015-2016	2016-2017	2017-2018	Total
Structural factor at the level of sectors	+17	+6	+1	+24
Structural factor at the level of sub-sectors	-3	+4	-3	-2
Economic activity	+3	+14	+19	+36
Technological factor	-6	-15	-9	-30
Climatic factor	+22	-11	+12	+23
Use of production capacities	-3	-1	-1	-5
Provision of amenities	-1	-1	-1	-3
Total	+27	-4	+18	+41

The table has been compiled by the authors as per data [6].

The increase in energy consumption due to the structural changes in the economy is primarily attributed to a high growth rate of the mining industry, particularly in 2016 as compared to 2015. The contribution of the economic activity is determined by Russian GDP growth after its maximum in 2015 caused by economic consequences resulting from sanctions against Russia declared in 2014. Economic regeneration led to an increase in energy demand, to varying degrees, in almost all sectors of economy. Climatic factor clearly demonstrates the dependence of the consumed energy on the variation of heating degree-days, namely the decrease in 2017 and increase in the colder years 2016 and 2018. Technological factor and provision of amenities are the most representative for assessment of the changes in energy efficiency of an economy. The former leads to the savings of the fuel and energy resources due to modernization of the engineering capabilities and implementation of new technologies. The latter, along with the growth of the availability of energy-consuming devices, demonstrates the level of use of public utilities by households. Over three years, energy savings due to these two factors for all sectors of economy amount to only 33 mln tons of coal equivalent, which is much less than the saving goals of the Program [8]. For example, in 2015 it amounted only to 102.23 mln tons of coal equivalent. Russia has the largest territory compared to any other country in the world. It consists of 85 territorial entities located in seven climatic zones with different natural resources, different level of economic development and regional governance. Russian regions demonstrate different socio-economic indicators and do not have the same potential for reduced energy consumption. Therefore, it would seem reasonable to assess the enhancement of energy efficiency of a regional economy not only through the changes in energy intensity of the gross regional product (GRP), but using disaggregated indicators for each sector in accordance with a “pyramidal approach” [10].

### 3. Challenges and prospects for enhancement of energy efficiency in the Sverdlovsk region

The Sverdlovsk region with its area of 194.3 thousand km<sup>2</sup> is inhabited by 4.315 mln people, 84.9% of which is urban population. The Sverdlovsk region is one of the leading industrial regions of the Russian Federation with highly differentiated economy and large reserves of various mineral resources. It is among the top ten in terms of many socio-economic indicators. GRP in the Sverdlovsk region amounts to 2.8% of the total Russian GRP. According to the Federal Service of State Statistics, with an increase in GRP in the Sverdlovsk region, its energy intensity decreases within the period from 2015 to 2018 (Table 3). GRP energy intensity in the Sverdlovsk region is 1.7 times higher than Russia's GDP energy intensity mainly due to a higher share of manufacturing in GRP. An essential share in the Sverdlovsk region belongs to high energy consumption sectors, such as ferrous and non-ferrous industry, machine building industry, metalworking production, and chemical engineering, which accrue to more than 70% of the manufacturing sector. Quantifying contribution to the changes of regional energy consumption at this stage is not feasible due to the lack of data. The main share of the fuel and energy resources in the Sverdlovsk region accrues to natural gas (59.2%) and coal (32.5%) which are imported from other regions.

**Table 3.** GRP energy intensity in the Sverdlovsk region.

Parameter	2015	2016	2017	2018
GRP in current prices, mln RUB	1,822,835	1,990,836.7	2,130,909.8	2,277,576.3
Volume index in constant prices, as a percentage over the previous year	97.3	101.9	102.0	102.3
Share of manufacturing in GRP (in the Sverdlovsk region/Russia), %	30.3/17.2	30.5/17	31.1/17.4	32.5/18
GRP energy intensity in the Sverdlovsk region, kgoe/10000 RUB (in current prices/in prices of 2012)	189.9/234.8	186.6/247.2	160.3/224.1	NA
Russia's GDP energy intensity, kgoe/10000 RUB (in current prices/in prices of 2012)	106.8/129.9	104.9/131.7	99.5/132.22	NA

The table has been compiled by the authors as per data of the Federal Service of State Statistics [11].

These data are provided for 2018 [12] but such a structure of the energy resources in use existed throughout the previous period. A higher share of coal in the fuel and energy balance of the region is attributed to the presence of the Russia's largest coal power plant, *Reftinskaya State Power Station*. Regional electricity and heat production markets are highly concentrated. In the structure of distribution of total capacity of power plants, the largest share belongs to one company, namely *Enel Russia* (PAO, 52%) [13]. Concentration index for the three largest electricity producers is 72%. The main share of thermal power of energy facilities within the territory of the region belongs to the *Sverdlovsk* branch of *T Plus* (PAO, 32%). The study of electricity retail markets within the territory of the Sverdlovsk region in 2018 performed by the Regional Office of the Federal Antimonopoly Service revealed high concentration within the geographical boundaries of the zone of activity of such last resort suppliers as *Ekaterinburgenergosbyt* (AO) and *MRSK Urala* (IDGC of Urals, OAO) and medium concentration for the last resort supplier *EnergosbyT Plus* (AO). The analysis of the final demand pattern for the fuel and energy resources in the Sverdlovsk region over the past three years (Table 4) demonstrates an annual increase in energy consumption primarily due to the growth of industry with its share of more than 64% of total consumption in 2018.

**Table 4.** Consumption of the fuel and energy resources across the sectors of economy in the Sverdlovsk region, thousand tons of coal equivalent\*.

Sector	2016		2017		2018		Deviation, %		
	Quantity	%	Quantity	%	Quantity	%	2017/ 2016	2018/ 2017	2018/ 2016
Final consumption of energy resources	20,710.7	100	21,044.5	100	22,341.9	100	101.61	101.62	107.88
Industry	12,163.7	58.73	12,279.9	58.35	14,354.9	64.26	100.96	116.90	118.02
Transport and communication industry	2,367.1	11.40	1,858.5	8.83	1,593.4	7.13	78.51	85.74	67.31
Services	699.4	3.38	1,186.9	5.64	1,140.3	5.10	169.70	96.07	163.04
Households	5,257.5	25.39	5,246.9	24.93	5,038.5	22.55	99.80	96.03	95.83
Other	213.9	1.10	472.2	2.25	214.8	0.96	220.76	45.49	100.42

\*The results do not take into account the use of fuel and energy resources as a raw material. The results have been calculated by the authors as per data [12, 14, 15].

Households are the second largest consumer of energy resources (more than 22% in 2018) primarily in the housing and community amenities sector (see Table 5). Over three years, the volume of fuel and energy resources in this sector decreased by 219 thousand tons of coal equivalent, which equals to 4% as compared to 2016, with the decrease in population in the region by 13.6 thousand people and increase in the total area of residential premises by 3,468 thousand m<sup>2</sup> [16].

**Table 5.** Consumption of the fuel and energy resources by the households of the Sverdlovsk region, thousand tons of coal equivalent.

Fuel and energy resources	2016		2017		2018		Deviation, %		
	Quantity	%	Quantity	%	Quantity	%	2017/2016	2018/2017	2018/2016
Oil products	1,451.2	27.6	1,440.5	27.5	1,356.9	26.9	99.3	94.2	93.5
Natural gas	324.3	6.2	537.8	10.3	460.1	9.1	165.8	85.6	141.9
Electric energy	619.3	11.8	631.4	12.0	643.6	12.8	102.0	101.9	103.9
Thermal energy	2,654.5	50.4	2,626.4	50.0	2,544.8	50.5	98.9	96.9	95.9
Coal and others	8.1	4.0	10.78	0.2	33.1	0.7	133.1	307.1	408.6
Total	5,257.5	100	5,246.9	100	5,038.5	100	99.8	96.0	95.8

The results have been calculated by the authors as per data [12, 14, 15].

The main share in the structure of energy consumption by households belongs to thermal energy (about 50%), which is attributed to a large number of heating degree-days within the continental climatic zone. The quantity of consumed oil products and thermal energy decreased between 2016 and 2018. The enhancement of energy efficiency in the housing and community amenities sector demonstrates a decrease in the average specific consumption of energy resources in the region (Table 6), except for electricity. Though specific consumption of thermal energy per one square meter of living space decreased from 0.210 Gkal in 2015 to 0.193 Gkal in 2018, the central heating system still demonstrates substantial losses coming from ageing of the utilities (more than 60%). As of 2018, 3,018.8 km of utilities out of total 7,611.0 km of steam and heating systems of the region must be replaced, which amounts to approximately 40%. Accurate records of consumed energy resources and provision of full income from their use are ensured by communal metering devices. In 2018, the overall level of availability of such devices in the multi-family dwellings in Russia amounted to 61%, including 71% for electricity meters, 65 % for hot water meters, 53% for cold water meters, and 3% for gas meters [6].

**Table 6.** Average specific consumption of energy resources by the households of the Sverdlovsk region.

Parameter	2015	2016	2017	2018
Specific water consumption per household, m <sup>3</sup> per person	60.5	58.5	56.8	55.1
Specific thermal energy consumption in multi-family dwellings, Gkal/m <sup>2</sup>	0.210	0.207	0.202	0.193
Electricity consumption, kWh per one person	NA	1,164	1,188	1,214
Availability of communal thermal energy metering devices in multi-family dwellings, %	62	65	67	63

The table has been compiled by the authors as per data [12, 14–16].

Significant savings of primary energy resources are achieved by adoption of technologies with high energy efficiency in the housing and community amenities sector. The key results in 2018 demonstrated an extremely insignificant level of innovative transformations:

- The share of multi-family dwellings put into operation with increased energy efficiency classes amounts to 27% within Russia.
- The share of multi-family dwellings fitted with individual heating units with weather compensators amounts to 5% within Russia.
- The share of LED bulbs in external lighting amounts to 16% within the region against 26% within Russia.

Achievement of significant results in energy savings and enhancement of energy efficiency of an economy of any sector requires, first of all, high levels of investments, which are necessary both for the modernization of utility networks of all energy resources and for the implementation of high energy-saving technologies. Budgetary provisions and third-party financing (Table 7) are clearly insufficient to meet the objectives [17].

**Table 7.** Funding levels provided for energy savings and enhancement of energy efficiency, mln RUB.

Territorial entity	2015		2016		2017		2018	
	Budgetary funds	Extrabudgetary funds	Budgetary funds	Extrabudgetary funds	Budgetary funds	Extrabudgetary funds	Budgetary funds	Extrabudgetary funds
Sverdlovsk region	448	36,877	275	4,353	834	1,129	1,107	6,202

The table has been compiled by the authors as per data [6, 18].

Additional attraction of extrabudgetary funds and their efficient use are feasible through public private partnership via performance contracts and concession agreements. The Sverdlovsk region is one of the leaders with regard to total cost of performance contracts among Russian territorial entities in 2018 with 411.6 mln RUB (7.1% from total cost within Russia). There are currently 40 concession agreements with total amount of long-term investments of 20.4 bln RUB signed by municipalities located within the territory of the Sverdlovsk region.

#### 4. Conclusions

1. Energy efficiency enhancement rate in Russia lags behind that of the states with advanced economy over the last decade. Primary energy saving goals have not been reached due to insufficient modernization of existing engineering capabilities and low rates of implementation of energy intensive technologies.

2. GRP energy intensity in the Sverdlovsk region exceeds the value of GDP energy intensity of Russia due to essential share of industrial manufacturing characterized by high consumption of energy resources, as well as harsh weather conditions. Regional markets of production, transfer and supply of all kinds of energy are characterized by high level of concentration and lack of competitors. The prevailing centralized energy resources supply system is not always economically feasible and leads to high technical energy losses.

3. Households are the second largest energy consumer. The ageing of communal infrastructure (60%) leads to high losses in the networks. Insufficient availability of metering devices for residential premises leads to commercial losses in the housing and community amenities sector. Low level of implementation of energy-saving technologies serves as a barrier to the reduction of specific consumption of energy resources.

4. Further enhancement of energy efficiency of the regional economy is only feasible with attraction of extrabudgetary investments and their efficient use through an increase in the number of performance contracts and conclusion of concession agreements for communal infrastructure through a tender process.



5. The article provides an analysis of energy consumption in the Sverdlovsk region built on fuel and energy balances over the past years with assessment of the factors influencing the GRP energy intensity.

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